UNIVERSITÉ DE MONTRÉAL

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MORAL HAZARD AND EXPERIENCE RATING: AN EMPIRICAL ANALYSIS*

by

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*We thank M. Bienvenu, D. Bilodeau, M. Bisaillon, P. Cossette, M. Dagenais, T.C. Liem, and M. Pellerin for their contribution to this research and the Régie de l'assurance automobile du Québec and the Huebner Foundation for their financial support. Comments and suggestions by Richard Arnott and participants in seminars at Ecole Polytechnique (Paris), Université de Toulouse, Université de Louvain, Université de Montréal, University of Pennsylvania, University of Alberta and Université Laval, in meetings of the Econometric Society, the Société canadienne de Science économique, the Société suisse d'économie et de statistique and in the Risk Theory Seminar of the American Risk and Insurance Association are gratefully acknowledged. Of course, we remain solely responsible for the content of this paper.

Cette étude a été publiée grâce à une subvention du fonds F.C.A.R. pour l'aide et le soutien à la recherche.

Université de Montréal
Centre de recherche sur les transports - Publication #428
February 1986 - Revised May 1987

Dépôt légal - 2e trimestre 1987

ABSTRACT

For many years, economists and actuaries have studied multiperiod insurance contracts independently and differently. We aim in this paper at reducing the gap between empirical studies on the determination of insurance premiums and theoretical studies on moral hazard and experience rating. The first objective is to verify empirically the proposition that past experience is a good predictor of risk by using data from a random sample consisting of 19,013 drivers. The second objective is to use the results to construct a multiperiod pricing formula for automobile insurance in order to reduce the ill-effects of moral hazard.

Key words : automobile insurance, moral hazard, experience rating, Probit.

RÉSUMÉ

Pendant plusieurs années, les économistes et les actuaires ont étudié les contrats d'assurance à plusieurs périodes indépendamment et différemment. Ce texte présente une première analyse économique empirique sur le risque moral et la tarification en fonction de l'expérience passée tout en faisant référence aux études actuarielles empiriques. Le premier objectif est de vérifier empiriquement la proposition que l'expérience passée est un bon prédicteur des risques individuels en utilisant des données d'un échantillon de 19 013 conducteurs. Le deuxième objectif est d'utiliser les résultats obtenus pour développer une formule de tarification pour l'assurance automobile afin de réduire les effets indésirables associés au risque moral.

Mots-clés : assurance automobile, risque moral, tarification en fonction de l'expérience, Probit.

For many years, economists and actuaries have studied multiperiod insurance contracts independently and differently. In the economic literature, discounts and penalties are introduced mainly to "counteract the inefficiency which arises from moral hazard" (Rubinstein and Yaari 1983), while in the actuarial literature, the "main purpose - besides encouraging policyholders to drive carefully - is to better assess the individual risk so that everyone will pay, in the long run, a premium corresponding to his own claim frequency" (Lemaire 1985). Moreover, actuaries have produced many studies on both the estimation of accidents distributions and the calculation of premiums, while economists have concentrated on more theoretical aspects of individual behavior under uncertainty and market equilibrium outcomes. We aim in this paper at reducing the gap between empirical studies on the determination of insurance premiums and theoretical studies on moral hazard and experience rating.

Since the pioneering work of Arrow (1963) and Pauly (1968), many economists have contributed to the analysis of moral hazard. According to the insurance literature, moral hazard is defined as the effect of insurance on the incentives of the insured to either take protective actions or simply be careful, because the insurer cannot observe these activities. In single-period models, Shavell (1979a, 1979b) and Holmstrom (1979) have shown that partial insurance coverage (coinsurance and deductible) reduces the misallocation of resources caused by the asymmetrical information.

More recently, Radner (1981, 1985), Rubinstein and Yaari (1983), Henriet and Rochet (1984), Rogerson (1985) and Boyer and Dionne (1985, 1987a) have analyzed multiperiod insurance contracts. In particular Rubinstein and Yaari derived characteristics of insurance contracts which could eliminate the inefficiencies associated with moral hazard and Boyer and Dionne extended their study to cases where the self-protection activities of an agent generate externalities for other agents. These authors obtained that moral hazard inefficiencies can be eliminated, or almost, when the number of periods is infinite or very large and the discount rate is zero or very small.

An important feature of multiperiod insurance models is that an individual's past experience is a good predictor of the probability of future losses. The insurer cannot directly observe self-protection activities, but an individual's past experience is a proxy variable for the risk the individual represents. Moreover, this approach enables the insurer to increase the incentives for taking care, since a good past record means a lower premium.

However, the individual's past experience approximates not only self-protection activities but also the individual's risk exposure and skill as a driver. The latter two would also imply different probabilities of accident for given self-protection activities. The insurance industry uses risk categorization based on age, sex and marital status to approximate these factors in order to reduce the problem of adverse selection (Dahlby 1983 and Hoy 1982). Adverse selection is not a significant problem in this study since insurance is compulsory for all drivers in the population studied. However, risk classification remains useful in order to isolate the effect of moral hazard. We do not have direct observations of driving skills and risk exposure. Therefore, we use proxy variables, such as age, sex, experience, type and class of driver's licence, place of residence and period of validity of the driver's license, to take account of the other features affecting the probability of accident.

Our first objective is to verify the empirical proposition that past experience is a good predictor of risk by using data from a random sample consisting of 19 013 drivers. We computed estimates, by using the Probit estimator, of the probability that a given driver will be involved in one or more car accidents in period t as a function of 7 groups of explanatory or control variables, plus the driver's past record represented by 3 variables, that is the number of accidents, the number of demerit points and the number of license suspensions for criminal

offenses. As we will discuss in more details below, the sample used in this study has significant original characteristics. It contains data on individual drivers on a yearly basis for a three-year period and represents a random sample gathered from the entire population of Quebec drivers. Such a sample could be constructed at a reasonable cost because the information on the variables used is collected by the Regie de l'Assurance Automobile du Quebec (RAAQ) which is responsible for the public insurance of bodily injuries and also for the Highway Code and road safety in general. Obtaining such a sample in an area where no such central agency exists could be very costly (see Ferreira 1970, 1971 for a discussion of this issue).

Researchers have proposed for a long time in the actuarial literature the use of the individual's past experience to determine premiums in insurance contracts (Ferreira 1970, 1971, 1974; Lemaire 1985). They have established different methods of merit rating in order to set the insured's premium according to past experience (as an equity consideration), and to deter people from hazardous driving (as an efficiency consideration). They have also investigated the impact of merit rating on ratemaking efficiency (Freifelder 1985). These researchers usually estimate a Compound Poisson distribution to describe the empirically observed distribution of accidents and they make use of Bayes' theorem to calculate individual premiums as a function of past experience only. We will show that it is possible to compute from our multivariate Probit estimates the probability of accident in period t as a function of the individual's characteristics and past experience as a driver. The main difference between the actuarial methodology and the one presented in this paper, is that while the former can be used to show that individuals represent different risks and thus to justify experience rating, it cannot isolate the individual factors which explain why individuals represent different risks, for instance, it cannot isolate driver skill and risk exposure from moral hazard factors.

Our second objective is to use these results to construct a pricing formula for automobile insurance. To fully exploit our data on past experience, we replace the claims history of the individual as used in Rubinstein-Yaari by the history of the probability of accident as estimated each period from our multivariate Probit model. We show by simulation that both methods are equivalent. Examples are given to illustrate that point.

Section I presents the basic theoretical model. Section II contains the estimated coefficients of both the Poisson and the Compound Poisson aggregate models and the estimated coefficients of two disaggregate multivariate Probit models; estimated probabilities of accident as functions of past experience are also calculated. In section III multiperiod insurance contracts under moral hazard are again considered and, using our empirical results from the Probit models, a pricing formula in the spirit of the Rubinstein-Yaari formula is derived. The conclusion summarizes the main results of the paper and presents a discussion of some avenues for future research.

I. THE THEORETICAL MODEL

Let us consider a model in which there are two possible states of the world: a first state corresponding to "no accident" with a probability of occurrence $(1-p(x,i))$ and a second state corresponding to "accident" with a probability $p(x,i)$, where x represents the level of care and i is a vector of variables characterizing an individual. We shall assume that $p(x,i)$ is decreasing and strictly convex in x, $p_1(x,i)<0$ and $p_{11}(x,i)>0$.

The choice of x for a typical individual can be characterized as the maximizer of the expected utility, a function of wealth. Defining S as initial wealth, L as monetary loss incurred in an accident [L can be interpreted as the average loss in an accident; we do not study here the distribution of losses given that an accident has occurred],

P as the insurance premium, and q as the amount of insurance coverage, the expected utility of the typical individual is therefore the following:

$$E[U] = (1-p(x,i))U(S-P-C(x)) + p(x,i)U(S-P-L+q-C(x)) \qquad (1)$$

where U is a twice differentiable, increasing and strictly concave utility function of wealth, $U'>0$ and $U''<0$, and C is an increasing and convex expenditure function of x, $C'>0$ and $C''>0$ with $C(0)=0$.

Without asymmetrical information, x and i are observable and the optimal choice of q and x is obtained from the maximization of (1) under the constraint that the insurer be in equilibrium, that is, $P = p(x,i)q$, assuming actuarially fair insurance pricing. Under the above assumptions, full insurance $q = L$ is optimal and the optimal amount of care x^* satisfies the following equation:

$$-p_1(x^*,i)L = C'(x^*) \qquad (2)$$

where the left hand side is the marginal benefit of care and the right hand side is its marginal cost. Under perfect information, experience rating has no value and single-period full insurance contracts are optimal (see Townsend 1982 for a detailed discussion of this issue and Boyer, Dionne and Kihlstrom 1987 for an analysis of the value of experience rating under imperfect but symmetric information).

Under asymmetrical information, such contracts cannot be used since x is not directly observable by the insurer. With full insurance and fixed premiums, the individual has no incentives to choose a positive value of x; therefore, in single-period contracts, second-best solutions under moral hazard involve partial insurance, $q<L$, implying a welfare loss compared with a first-best solution.

Multiperiod contracts can reduce the welfare loss caused by moral hazard. We shall concentrate here on the analytical framework from Radner (1981, 1985) and Rubinstein and Yaari (1983) and present an empirical proposition based on this type of model (see Dionne 1983 and Dionne and Lasserre 1985 for an application of this framework to the adverse selection problem). The important feature of multiperiod contracts based on past experience is that they motivate the insured to choose a higher positive level of care activities in order to reduce premiums paid over time. The insurer (agent 1) makes the following proposal to the client (agent 2): "Since I cannot observe directly your level of care activities, I will use your past experience in order to approximate them".

The Rubinstein-Yaari insurance contract is negotiated in the first period and provides for the premium to be set at the beginning of each following period from the accumulated information on the past experience of the insured. Insurance coverage does not change over time and corresponds to full insurance. For each period, the insurer sets the level of the insurance premium, P^t, as a function of past experience in a way suggested below and the insured must decide to purchase insurance or not and must choose the level of care activities. Each agent knows the strategy of the other. At the end of each period t, the insurer knows if the individual was insured or not during that period and previous periods and in the former case, whether the individual had an accident in any of those periods. The insured is aware of those accident involvements in all periods up to t.

Without discounting, we can assume that agents maximize the average value of their payoff over time. We can then determine which strategy the insurer can use to reduce and possibly eliminate inefficiencies caused by moral hazard. Rubinstein and Yaari (1983) have proposed the "no-claims discounts" strategy which can be written as follows:

$$P^1 = P^* = p(x^*,i)L$$

$$P^t = \begin{cases} P^* \text{ if } \left[\frac{1}{N(t)}\right] \sum_{s=1}^{t-1} L^s < p(x^*,i)L + \alpha^{N(t)}, \ t>1 \\ PP \text{ otherwise} \end{cases} \quad (3)$$

where x^* is the Pareto optimal level of care activities

i is a vector of observable individual characteristics;

L^s is the observed claim in period s, $L^s \in \{0,L\}$; a claim is filed only if the individual was insured in period 5;

$N(t)$ is the number of periods before t during which the individual was insured;

$\alpha^{N(t)}$ is a statistical tool used to avoid penalizing too often those who chose x^* but were unlucky, while allowing the detection of those who deviate from x^*; it is equal to $\left[\frac{2\gamma\sigma^2 \log \log N(t)}{N(t)}\right]^{1/2}$ for $N(t) \geq 3$ and arbitrarily large otherwise; this $\alpha^{N(t)}$ is obtained from the Law of the Iterated Logarithm which says that given a sequence of independent identically distributed random variables $\{L^v\}$ with mean $\bar{L} = p(x^*,i)L$ and variance σ^2 then, for any $\gamma>1$, almost surely

$$\limsup_T \left| \frac{1}{T} \sum_{v=1}^{T} L^v - \bar{L} \right| < \alpha^\gamma ;$$

PP is a penalty premium such that

$$U(S-PP) < \max_x (1-p(x,i))U(S-C(x)) + p(x,i)U(S-L-C(x)),$$

that is the individual would not buy a one-period full insurance contract with premium PP.

Rubinstein and Yaari (1983) have shown that the single-period first-best solution (i.e. with perfect information), $q = L$ and $x = x^*$, is enforceable under (3) as a noncooperative equilibrium, i.e. $x = x^*$ is a best-reply to (3), and therefore "by adopting a suitable 'no-claims discounts' strategy, the insurer can enforce upon the [insured] a strategy under which the latter always exercises the proper amount of care, thus wiping out the ill-effects of moral hazard" (p. 86). More generally, they proved a version of the Folk theorem: the insurer can enforce as a noncooperative equilibrium any individually rational outcome for a single-period contract by adopting an appropriate no-claims discounts strategy.

Rubinstein and Yaari (1983) obtained their result in an infinite horizon model with no discounting. However, multiperiod contracts can come very close to Pareto-efficient outcomes if (Radner 1985) the discount rates are small in an infinite horizon framework; and also if (Radner 1981) the number of periods is large in a no discounting framework, provided one is willing to accept a weak form of bounded rationality, i.e. agents' strategies which are quasi-best replies to one another (an ϵ-equilibrium). Radner showed also that multiperiod contracts can be Pareto-superior to single-period contracts when the number of periods is large and the discount rates are small. Finally, the above results can be extended to situations where externalities between agents are present if the insurer, public or regulated, uses the socially optimal level of care in order to set the premiums (Boyer and Dionne 1985, 1987a).

II. AN EMPIRICAL ANALYSIS OF AUTOMOBILE ACCIDENTS.

In Québec, the automobile insurance plan is a mixed system. Bodily injuries are insured, up to a maximum amount, by a provincial state-owned insurance company, the Régie de l'Assurance Automobile du Québec (RAAQ). Property damages are insured by a competitive system of private insurance

companies. The public insurance scheme for bodily injuries is compulsory for all drivers. It is a centrally administrated and no-fault system which covers every driver up to the maximum coverage, which represents full coverage for about 85% of the population. Although a driver has the option of purchasing additional insurance coverage from private companies (on which we have no data), the no-fault system suspends the right to sue for bodily injuries. Car owners must also buy from a private company a minimum insurance covering responsibility for property damages to another party. Everything else is optional (See Boyer and Dionne 1987b for more details).

The public insurance plan has several characteristics which are particularly interesting in the present context. First, insurance for bodily injuries is compulsory for every driver and second, it is provided by a single public insurer, the RAAQ. These characteristics make it possible to design contracts which extend over many periods with the same insurer. As mentioned in section I, an appropriate contract could induce a driver to choose an efficient level of self-protection activities in the presence of both moral hazard and externalities.

The determination of an efficient pricing formula based on that of Rubinstein-Yaari requires three basic elements: first, an empirical measure of the accuracy of past experience as a predictor of the probability of future losses or accidents; second, a measure of the impact of insurance pricing on the choice of self-protection activities by individuals; and finally, a procedure to determine the socially efficient level of road safety and self-protection activities. This study will report on a measure of the first element and on the determination of an insurance pricing formula which would depend indirectly on self-protection activities. Our data set does not permit an explicit empirical measure of the second element since it corresponds to a period (1980-83) of no change in the insurance plan. However, in a related study, Gaudry (1984) shows that the introduction of the new plan

in 1978 is responsible for an increase in the number of accidents. One particular change in 1978 was the introduction of a no-fault insurance plan along with a new pricing system for the public insurance plan: every driver pays the same premium whatever the risk he represents and whatever his past experience. Gaudry's result suggests that there is a moral hazard problem under the new plan (see Boyer and Dionne 1987b for more details). Moreover, as we indicated in the introduction, adverse selection is not an important factor to explain differences in the probabilities of accident since insurance is compulsory. We do not address explicitly the third element in this study but we show that when a particular level of social care has been chosen, the proposed pricing formula based on our empirical estimates is equivalent to that of Rubinstein and Yaari.

The sample upon which the study is based includes a complete set of data on 19 013 randomly selected drivers over a three-year period, from August 1980 to July 1983. This sample has many advantages. First it was randomly gathered from among the entire population of Québec drivers and therefore, is likely to be more representative than a sample of insured drivers from a given company. Second, it contains four types of information on each driver for each given year: personal characteristics appearing on the driver's license itself (age, sex, experience, place of residence, driving restrictions, class of license, period of validity), the number of past involvements in accidents, the cumulative number of demerit points, and finally, the number of license suspensions for criminal offenses. Third, the data is historical and can be updated at minimal costs to eventually cover as many years as desired. This is a very important advantage of the data since the probability of accident in any given year is small and the desired result is to induce safety-generating behavior through long-term insurance contracts. Finally, this data makes it technically feasible to send a questionnaire to a subsample of drivers in order to collect additional information on driving habits, risk exposure, socioeconomic characteristics, etc... It must be noted

however that to preserve confidentiality, the name and address of the individual drivers are not known, but a correspondence table is kept at the RAAQ for updating the files.

The remainder of this section is organized as follows: the hypothesis that Québec car drivers differ regarding the probability of accidents is first tested; then the probability of accident as a function of individual characteristics and of past experience is estimated. Section III presents the insurance pricing formula.

II.1 ESTIMATING THE DISTRIBUTION OF ACCIDENTS

It is reasonable to suppose that for a given individual, the probability of being involved in a car accident satisfies the following conditions: the probability of accident is proportional to the number of periods considered, the probability of having more than one accident in a period is small and accidents are independent. The Poisson distribution does satisfy the above characteristics and has therefore been used as a first choice to represent the distribution of accidents. The probability that an individual will be involved in k accidents over t years is then:

$$p(k|t,\lambda) = \frac{e^{-\lambda t}(\lambda t)^k}{k!} \qquad (4)$$

where λ is both the mean and variance of the distribution. However, using a Poisson distribution to represent the observed distribution of accidents for a group of individuals supposes implicitly that all individuals have the same probability of being involved in one or more accidents. This last feature is very restrictive.

If, on the other hand, we assume that λ varies between individuals and that for a given individual the distribution of accidents follows a Poisson distribution, then it will be convenient to suppose that λ follows a Gamma density function,

$$f(\lambda) = \frac{\lambda^{a-1}\tau^a e^{-\tau\lambda}}{\Gamma(a)}, \qquad \tau>0 \text{ and } a>0 \tag{5}$$

with mean a/τ and variance a/τ^2, $\Gamma(a)$ being the Gamma function. From the distribution of λ, the *average* probability of being involved in k accidents over t years becomes the Compound Poisson distribution:

$$P(k|t,a,m) = \int_0^\infty P(k|t,\lambda)f(\lambda)d\lambda$$

$$= \frac{\Gamma(k+a)}{k!\Gamma(a)}\left[\frac{a}{a+mt}\right]^a\left[\frac{mt}{a+mt}\right]^k \tag{6}$$

where the mean is $m = a/\tau$ and the variance is $(a/\tau)(1+1/\tau)$ (see Lemaire 1985 for more details). If the distribution of accidents is better represented by the Poisson distribution (4), it would suggest that all individuals represent the same risk and, therefore, that differential insurance pricing would have no supporting empirical evidence. We estimated the two distributions (4) and (6) for the period between August 1982 and July 1983. Results are reported in Table 1, where k is the number of accidents and n_k is the number of individuals with k accidents. For the Poisson distribution, we obtain an estimated $\hat{\tau}$ of 0.0701; observed and predicted values for n_k give a χ^2 of 55.12 thereby rejecting the hypothesis that the distribution of accidents follows a Poisson distribution. As for the Compound Poisson, the maximum likelihood estimates are $\hat{a} = 0.6960$ and $\hat{\tau} = 9.9346$ and therefore $\hat{m} = 0.0701$; observed and predicted values for n_k give a χ^2 of 2.16. We cannot therefore reject the hypothesis that drivers are different according to the risk they represent. These results provide the necessary empirical justification for proceeding with the econometric estimation of the probability of accident, p(x,i), by controlling for the individual characteristics, vector i, in order to isolate properly the implied choices of self-protection activities behind the results of Table 1. It is interesting to note that based on the parameter estimates of the Compound Poisson distribution, equation (6) gives the probability of having 0 accident (k=0) in 1982-83 (t=1) as 0.935 and therefore

$$P(k \geq 1 \mid t=1,a,m) = 0.065$$

This value corresponds to the mean of the estimated individual probabilities of accident to be obtained below from the Probit model.

[INSERT TABLE 1 HERE]

II.2 THE ECONOMETRIC ESTIMATION OF THE PROBABILITY OF ACCIDENT

As mentioned previously, the econometric model estimated here explains the probability of accident with variables defined from the characteristics of individual drivers and with variables indirectly representing the individual driver's choice of road safety activities. The first group of variables includes age, sex, number of years since the first license was obtained, place of residence, driving restrictions, class of the driver's license, and period of validity of the license. Each variable, except for the latter one, is represented by a set of dichotomous variables, as is customary the case in the insurance business. For example, the "age" variable is represented by 8 dichotomous variables with the age group 16-19 in the constant. The exact meaning and measure of each variable are presented in Appendix A. The second group consists of proxy variables for the unobservable choices of self-protection activities by the individual. It corresponds to the individual's past driving experience. Three such variables appear in our sample: the cumulative number X of demerit points over the two previous years, the number Y of license suspensions for criminal offenses in the previous year (we have no data on this for 80-81) and, finally, the number Z of accidents the individual was involved in during the two previous years.

In the Rubinstein-Yaari theoretical framework, only past claims, measured here by the past number of accidents (the third proxy above) are considered. However, it seems reasonable to conjecture that observing three proxies for care activities rather than only one should allow us to

design a Pareto superior contract when the number of periods is finite and discounting is present. In any case, empirical results for two models, a MODEL 1 considering only the third proxy Z above and a MODEL 2 considering all three proxies X, Y and Z, are presented below.

A first possible specification is the Linear Probability model:

$$y_i = \alpha + \beta' w_i + u_i \qquad (7)$$

where $w_i=(x,i)$ and $E(u_i)=0$. The dependent variable y_i is dichotomous: $y_i=1$ if the i-th individual had one or more accidents during 1982-83, and $y_i=0$ otherwise. $E(y_i|w_i)=\alpha+\beta' w_i$ can be interpreted as the probability that $y_i=1$ since

$$E(y_i|w_i) = p(1|w_i)1 + (1-p(1|w_i))0 = p(1|w_i). \qquad (8)$$

However, the linear probability specification is far from being totally adequate when the dependent variable is dichotomous. First, there is a serious heteroscedasticity problem and second, $\hat{\alpha}+\hat{\beta}w_i$ may fall outside the range [0,1] for some w_i, which is troublesome if we interpret $E(y|w_i)$ as a probability. Although these problems are likely to be less serious given the large number of observations and variables, more adequate nonlinear models such as the Probit and the Logit estimators must be considered. We ran both but we report only the Probit estimates here since both sets of estimates turn out to be very close to their theoretical relationship (Maddala 1977), the Probit results are slightly better and since it does not matter much here whether we use the Probit or the Logit estimator (Amemiya 1981). [Also, because only 90 individuals had more than one accident in 1982-1983 and because the computational cost of multinomial Probit or Logit is very large given our sample size and number of variables, we elected to use a binary model only.]

The probability of accident is not observed as such. What is observed is not the probability of accident but rather whether the

individual had an accident. That is assumed to depend in part on a linear function of the individual's characteristics w_i, say $\alpha+\beta'w_i$, and in part on other unobserved features represented by a single random variable u_i. We can specify that the individual has an accident ($y_i=1$) when $\alpha+\beta'w_i+u_i>0$ and has no accident otherwise. Therefore, we observe only that driver i had at least one accident ($y_i=1$, i.e. $u_i>-\alpha-\beta'w_i$) or had no accident ($y_i=0$, i.e. $u_i<-\alpha-\beta'w_i$). Since the number of variables which influence the probability of accident, other than those included in w_i, is very large, it is reasonable to assume that u_i is normally distributed. Hence, the probability that driver i will be involved in at least one accident is given by the cumulative normal distribution function of u_i, that is

$$\text{prob}[y_i = 1 \mid w_i] = F(-\alpha-\beta'w_i) = \int_{-\infty}^{\frac{-\alpha-\beta'w_i}{\sigma}} (2\pi)^{-1/2}\exp(-\frac{s^2}{2})ds \qquad (9)$$

The likelihood function of the observations will be given by

$$LF = \left[\prod_{y_i=0} F(-\alpha-\beta'w_i)\right]\left[\prod_{y_i=1} (1- F(-\alpha-\beta'w_i))\right]$$

and the maximization of LF with respect to α and β [setting $\sigma = 1$, because LF is homogeneous of degree 0 in α, β and σ] gives the Probit estimator. Probit estimates $\hat{\alpha}$ and $\hat{\beta}$ for MODEL 1 and MODEL 2 are presented in Table 2 under the columns "Original coefficient". As a whole, the regressions are very significant. Moreover, the sets of significant variables are the same as those obtained with OLS (available upon request).

Table 2 also presents transformed coefficient estimates which can be directly interpreted as the variation in the probability of accident due to the presence of a given variable. Consider first the variables for which there is a reference group (age, sex, experience, region of residence). The transformed coefficient estimate for a variable in a given group is obtained as the difference between the probability of

accident (9) calculated by setting all the variables in that group at 0 and all the other variables at their sample mean, and the probability of accident obtained by setting all the variables in that group at 0 except for the variable under consideration which is set at 1 and setting all other variables at their sample mean. As an example, the otherwise average driver in the age group 35-44 has a probability of accident which is 3.1 percentage points lower than that of an otherwise average driver in the reference age group 16-19. Consider now the variables for which there is no reference group (driving restrictions, class of driving license, validity, X, Y, Z). Let w^k be such a variable and let $\bar{w}^k$ be its sample mean. The transformed coefficient estimate for w_k is the difference between the probability of accident (9) calculated for ($w_k=v_k$, $w_j=\bar{w}_j$ for all $j\neq k$) and its value calculated for ($w_k=v_k'$, $w_j=\bar{w}_j$ for $j\neq k$), where v_k equals 1 and v_k' equals 0 for a dichotomous variable and both may take different step values for a continuous variable. As an example of the former, consider the results of MODEL 2. The otherwise average driver with driving restriction A (RTSA = must wear glasses) has a probability of accident which is 2.5 percentage points lower than the otherwise average driver without driving restriction A. As an example of the latter, consider again the results of MODEL 2.

[INSERT TABLE 2 HERE]

The otherwise average driver with 5 demerit points (X=5) has a probability of accident which is 3.4 (0.6+2.8) percentage points higher than that of the otherwise average driver with no demerit points (X=0). Similarly, the otherwise average driver with 2 previous accidents (Z=2) has a probability of accident which is 3.4 points larger than that of the otherwise average driver with only one previous accident (Z=1).

It is interesting to note that the age variables are significant. In comparison with the reference group (i.e. the 16-19 year-old drivers), we see that drivers over 25 will have a lower probability of accident by

2.2 to 3.6 percentage points in the first model, and by 2.0 to 3.0 percentage points in the second model. Sex is significant, male drivers having a probability of accident 4.4 and 3.7 points higher respectively. The class of driving license is in general significant in explaining individual probabilities of accident, class 21 and 22 (truck drivers) and also 31 (taxi drivers) showing significantly higher probabilities of accident. As was mentioned above, these variables are likely to be proxies for driving skill and, more important, risk exposure. Our results are similar to those obtained by Dahlby (1983) and somewhat justify the use of those variables by insurers. However, individual measures of risk exposure and driver skill would clearly be more appropriate here. It is interesting to note that the place of residence variable is generally not significant, meaning that when individual information is available, this variable, used as proxy of risk by insurers, is of no use.

Our results also show that the above variables explain only in part the differences in probabilities of accident between drivers. Indeed, the three past experience variables X (demerit points), Y (license suspensions for criminal offense) and Z (past accident involvements) are significant. In MODEL 1, a single accident during 1980-81 or 1981-82 raises the probability of being involved in an accident in 1982-83 by 3.2 percentage points. Considering that the average probability of being involved in at least one accident is 6.5 %, the increase is important. In MODEL 2, 5 cumulated demerit point increase the probability of accident by 3.4 percentage points; one license suspension increases the probability of accident by 3.9 percentage points; and a single accident in 1980-81 or 1981-82 increases the probability of accident in 1982-83 by 2.5 percentage points.

Since the Probit estimator is nonlinear in the parameters, it is interesting to note that the average individual, defined by the vector of average values of the explanatory variables, has an estimated probability

of accident of 0.0530 in MODEL 1 and 0.0518 in MODEL 2. These are smaller than the mean of the estimated individual probabilities of accident, which is 0.065 in both models. This mean estimated probability differs also from the mean of the Compound Poisson distribution (0.0701) estimated previously, because we use a discrete variable to measure the number of accidents in the Compound Poisson model but a 0-1 variable (y=1 for one or more accidents) in the Probit models.

Let us consider the econometric results of the Probit estimator reported in Table 2 (MODEL 2). Since we are mainly interested in vector $\Omega=(X,Y,Z)$, we will concentrate on its impact on the probability of accident for an otherwise average individual, as defined by the average value of all variables not in Ω. It is useful to mention here that the correlation coefficients between X, Y and Z are $r_{xy}=0.07901$, $r_{xz}=0.22110$ and $r_{yz}=0.09431$. We can derive the following self explanatory tables.

[INSERT TABLE 3 HERE]
[INSERT TABLE 4 HERE]
[INSERT TABLE 5 HERE]

Tables 3, 4 and 5 bring out two important features. First the probability of accident in 1982-83 is a nonlinear convex function of each variable X, Y and Z. Second there is a reinforcement effect between those variables. For example, 5 demerits points increase the probability of accident by 0.032 (from 0.043 to 0.075), 1 license suspension increases it by 0.036 and 1 past accident increases it by 0.023; but the three combined increase the probability of accident by 0.134 (from 0.043 for X=Y=Z=0 to 0.177 for X=5, Y=1 and Z=1).

III. THE INCENTIVE COMPATIBLE MULTIPERIOD INSURANCE CONTRACT

Considering now the Rubinstein-Yaari results on the incentive properties of multiperiod insurance contracts of the type discussed

above, the econometric results can be used to design an empirical incentive compatible contract. The data allowed us to estimate the probability of accident from an individual's personal characteristics (vector i) and involvements in accidents over the previous two years (variable Z). This corresponds to MODEL 1. The Rubinstein-Yaari "no-claims discounts" contract is expressed in terms of the observed past average claim and the expected claim obtained for a proper behavior regarding self-protection. We can reformulate this contract in terms of the average estimated probability of accident in previous periods and the probability of accident obtained if the individual chooses an adequate level of self-protection activities. Therefore, the contract defined by (3) could be rewritten as follows:

$$P_i^1 = P_i^* = p_i^* L$$

$$P_i^t = \begin{cases} P_i^* \text{ if } \left(\frac{1}{t-3}\right) \sum_{s=3}^{t-1} p(i,Z_s) < p_i^* + \alpha_i^t \\ PP \quad \text{otherwise} \end{cases} \qquad (10)$$

where p_i^* is the socially efficient probability of accident for individual i (the determination of p_i^* is obviously not an easy task) and P_i^* is the actuarial premium corresponding to the socially efficient behavior in self-protection activities; Z is the number of accidents the individual was involved in over the previous two years, Z_s being the value of Z for period s, that is the number of accidents observed in s-1 and s-2; and p(i,Z) is the estimated probability of accident of an individual characterized by (i,Z) as obtained from the parameter estimates of MODEL 1.

Contract (10) can be interpreted as follows: considering that $p(i,Z_s)$ is the individual's estimated probability of accident in period s, given characteristics i and involvements in accidents Z_s over the years s-1 and s-2, then the individual is offered a full insurance contract at the premium P_i^* if the average of past estimated probabilities of accident is less than the probability of accident p_i^*

obtained for an adequate level of care, plus a statistical margin of error. Therefore, instead of Contract (3) expressed in terms of the average of the previous claims and a proper expected claim, we now have contract (10) expressed in terms of an average of previous estimated probabilities of accident and an efficient or proper probability of accident. The data and results of MODEL 1 enable us to readily compute such a contract.

To illustrate how such a contract can be designed from our results and to compare the Rubinstein-Yaari (RY) contract (3) and the Boyer-Dionne (BD) contract (10), we shall consider a driver with $i=\bar{i}$, that is, whose i is the average of the individual vectors of characteristics. We shall simulate "histories" of accidents randomly generated by a Poisson density function with parameter δ; since Z represents the number of accidents over a two-year period, its probability density function will be a Poisson function with parameter 2δ:

$$pr(Z) = \frac{e^{-2\delta}(2\delta)^Z}{Z!}$$

The expected value and variance of $p(\bar{i},Z_s)$ over time will be

$$Ep(\bar{i},Z) = \sum_{Z=0}^{\infty} \frac{e^{-2\delta}(2\delta)^Z}{Z!}\, p(\bar{i},Z)$$

$$\sigma^2(p(\bar{i},Z)) = \sum_{Z=0}^{\infty} \frac{e^{-2\delta}(2\delta)^Z}{Z!} \left[p(\bar{i},Z) - Ep(\bar{i},Z)\right]^2$$

Let us suppose, for consistency, that $\delta = 0.0701 = \hat{a}/\hat{\tau}$, the estimated mean of the Compound Poisson distribution (Table 1). Recalling that $E(Z)=\bar{Z}=2\delta$, then we obtain

$$Ep(\bar{i},Z) = 0.053$$
$$\sigma^2(p(\bar{i},Z)) = 0.00016$$
$$p(\bar{i},\bar{Z}) = p(\bar{i},0.1402) = 0.052$$

the difference between $\delta=0.0701$, $p(\bar{i},\bar{Z})=0.052$ and $Ep(\bar{i},Z)=0.053$ is due

to two reasons: first p(i,Z) is a nonlinear function of Z (convex in the region of interest) and second the dependent variable in the Probit estimator is a binary variable (y=1 if one or more accidents occurred) rather than a discrete variable such as the number of accidents.

Again for simplicity and consistency, let us consider as socially desirable and indicative of adequate behavior a probability of accident p^*, for $i=\bar{i}$, equal to $Ep(\bar{i},Z)=0.053$, as obtained above. The statistical margin of error, α^t, appearing in (10) is then

$$\alpha^t = \left[\frac{2\gamma(0.00016) \log \log t}{t} \right]^{1/2} \qquad (12)$$

where γ is a policy parameter. For $\gamma=4$, then α^t takes a value of 0.01022 for t=4 and 0.00922 for t=15. We can now restate the BD contract as follows: the individual will be charged an actuarial premium of $P^*=\delta L$ for year t if the past average estimated probability of accident $\left(\frac{1}{t-2}\right) \sum_{s=3}^{t} p(\bar{i},Z_s)$ is less than $p^*+\alpha^t=(.053)+\alpha^t$, where α^t is given by (12); he will be charged a penalty premium PP, otherwise. With an appropriately chosen penalty premium PP, the individual is induced to select the proper level of care implying an expected estimated probability of accident equal to p^*. Of course, even with the proper level of care, the individual may be unlucky and have to pay PP rather than P^*. However, α^t prevents the insurer from penalizing too often those who choose x^*.

The simulation will allow us to verify the above assertion and see how the value of γ affects the probability of paying PP when the individual chooses the proper level of care. To compare the above contract to the Rubinstein-Yaari contract, let us assume that L=1 and instead of the average of one-year claims and the expected one-year claim in the RY contract, let us use the past average of two-year claims and the expected two-year claim with overlapping years. Considering as socially efficient the behavior of the individual implicit in the

simulation above, the expected two-year claim is $E(Z_s|\delta=0.0701)=0.1402$ and the relevant value of α^t is

$$\alpha^t = \left[\frac{2\gamma(0.1402)\ \log\log t}{t}\right]^{1/2} \qquad (13)$$

since $\sigma^2(Z|\delta=0.0701)=0.1402$. For $\gamma=4$, the value of α^t is 0.3026 for t=4 and 0.2729 for t=15. Referring to the previously defined $\{Z_s\}$, the RY contract is the following: the individual is charged the actuarial premium δL if the past average value of Z_s, that is $\left(\frac{1}{t-2}\right)\sum_{s=3}^{t} Z_s$, is less than the expected value under the proper level of care 0.1402, plus α^t given by (13). The individual is charged the penalty premium PP otherwise.

We simulated 1000 cases of a 50-period contract and of a 100-period contract and 100 cases of a 1000-period contract. The results are summarized in Table 6.

[INSERT TABLE 6 HERE]

Let us consider the 50-period contract with $\gamma=4$. For the RY contract, expressed in terms of the average past claim (or number of accidents since L=1) the $\bar{i}$ individuals choosing the proper level of care will nevertheless be charged the penalty premium PP for an average 4.16% of the time. This represents an average 2.08 years over the 50-year contract. For the BD contract, expressed in terms of average past estimated probability of accident, the same individuals would be penalized an average 4.24% of the time or an average 2.12 years over the 50-year contract. For $\gamma=10$ however, these percentages drop to 1.03% and 0.89% respectively. As the number of periods increases, these percentages decrease and converge to 0.

Although Rubinstein and Yaari's results were derived in an infinite horizon model, it appears reasonable to design such a contract spanning a 50-year horizon or a 100-semester horizon. The problem of having a finite horizon and positive discounting may be less serious if the penalty premium PP and the parameter γ are set at appropriate levels. A high PP and a low γ would represent strong incentives to choose a high level of self-protection. However they would make it more likely that people who take adequate care would nevertheless be penalized merely because of bad luck.

The BD contract used for the simulations reported in table 7 is based on the Probit MODEL 1. An even more appropriate contract could be similarly designed from Probit MODEL 2 where three proxies of the individual self-protection choices are used. There is more information on self-protection in MODEL 2 with X, Y and Z than in MODEL 1 with Z only.

IV. CONCLUSION

There were two objectives in this paper: first, to verify how good past experience is as a predictor of risk, and second to design, from our empirical results, an insurance contract taking explicitly into account individual characteristics while remaining consistent with the Rubinstein-Yaari no-claims discounts contract. The first objective was achieved by testing and rejecting the hypothesis that all drivers represented the same risk, by designing a set of variables depicting individual characteristics and a set of variables to be interpreted as proxies for the individual's self-protection behavior, and, finally, by estimating two Probit models of the individual probability of accident. This led us to a very significant result: taking explicitly into account individual characteristics, we found that the three variables used as proxies of an individual's behavior, demerit points X, license suspensions for criminal offenses Y and past involvements in accidents Z,

are significant in explaining the probability of accident at the level of the individual driver.

The second objective was achieved by replacing the "observed claims" of the Rubinstein-Yaari contract by the "estimated probabilities of accident". This has the advantage of considering explicitly a set of individual characteristics, over which the driver has little or no control, and three proxies for self-protection behavior rather than only one. Hence, basing the contract on the estimated probability of accident allows for a more specific and better focussed treatment of moral hazard.

However, many problems remain unresolved. How to calibrate P_i^*, PP and γ in order first to provide real incentives, second to avoid penalizing good behavior, third to avoid the non-reporting of accidents, and fourth to meet a zero profit constraint for the insurer either in each period or over time? How to determine the socially efficient p_i^* as a function of i under both moral hazard and externalities? How will it change over time as the individual's characteristics change? If p_i^* changes over time, how should contract (10) be rewritten to take such changes into account?

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APPENDIX A

LIST OF VARIABLES USED IN THE ECONOMETRIC ANALYSIS

AGE: 8 dichotomous variables

A16 = 1 if, on August 1 1982, the driver is under 16 years of age. Some drivers fall into this category since the sample was taken on May 16 1983.
0 otherwise

A1619 = reference group

A2024 = 1 if, on August 1 1982, the driver is between 20 and 24.
0 otherwise

etc...

SEX: 2 dichotomous variables

SEXF = reference group

SEXM = 1 if male, 0 otherwise

EXPERIENCE: 7 dichotomous variables to measure the number of years since a driver obtained a first permit

EXP0 = 1 if permit obtained in 1982-83, 0 otherwise

EXPM1 = 1 if, on August 1 1982, the permit has been held for less than a year, 0 otherwise

EXP1 = 1 if permit was obtained between 1 and 2 years ago, 0 otherwise (reference group)

etc...

PLACE OF RESIDENCE: 11 dichotomous variables to capture the effect of the immediate environment of the individual driver

REG1 = 1 if the driver lives in the Lower St.Lawrence or Gaspé Regions
0 otherwise

REG2 = Saguenay-Lac St.Jean

REG3 = Québec city region

REG4 = Trois-Rivières

REG5 = Eastern Townships

REG6 = Montreal region: reference group

REG7 = Laurentians-Lanaudière

REG8 = Montérégie

REG9 = Outaouais

REG10 = Abitibi-Témiscamingue

REG11 = North-Shore and Nouveau-Québec

DRIVING RESTRICTIONS: 13 dichotomous variables to capture the effect of driving restrictions appearing on the driver license (type of license)

RTSA = 1 if the driver must wear glasses, 0 otherwise

RTSB = can drive during daylight only

RTSCG = must wear a hearing aid (C) or must drive a car with power brakes (L,N,P) or must drive a car with a left acceleration (R) or is subject to medical restrictions (S) or other restrictions (T) or has a temporary permit (W).

RTSD = must get a medical exam regularly

RTSH = can only drive a vehicle whose total weight is less than 5500 kg

RTSJ = must drive an automatic transmission equipped car

RTSK = must drive a car with power steering

RTSM = cannot drive a business vehicle, a bus, a minibus or a taxi

RTSO = cannot drive an emergency vehicle

RTSQ = must drive a car equipped with manual signals or a magic eye

RTSU = has a license valid for 6 months only

RTSY = cannot drive a taxi or an ambulance

RTSO = no restrictions

CLASS OF DRIVING LICENSE: 9 dichotomous variables to isolate the effect of the class of driving license (since class 41 and class 42 are almost mutually exclusive only class 42 is used as a variable; since no driver in our sample has class 61 only, this class is not used as a variable).

CL1112 = [1 if driver can drive a bus; include classes 13,41,42,61
0 otherwise

CL13 = minibus; includes 41, 42 and 61

CL21 = vehicle or set of vehicles whose weight may exceed 11000 kg; includes 22, 41, 42 and 61

CL22 = vehicle whose weight may exceed 11000 kg; includes 41, 42 and 61

CL31 = taxis; includes 41, 42 and 61

CL41 = vehicles or set of vehicles whose weight is less than 11000 kg (includes 42 and 61)

CL42 = vehicles of class 41 except public vehicles; includes 61

CL54 = motorcycle; includes 55, 56 and 61

CL55 = motorcycle of less than 400 cm^3; includes 56 and 61

CL56 = velomotor, includes 61

CL61 = tractor

VALIDITY: 3 continuous variables to measure the period of validity (number of days) of the driving license in a given year

VALA : period of validity (number of days) of the driver's license during 1980-81

VALB : period of validity (number of days) of the driver's license during 1981-82

VALC : period of validity (number of days) of the driver's license during 1982-83

DEMERIT POINTS: variable X is the number of demerit points cumulated over the two-year period between August 1980 and

July 1982 (see Appendix B)

SUSPENSIONS OF LICENSE: variable Y is the number of license suspensions for criminal offenses (see Appendix C) in effect during the year 1981-82

PAST INVOLVEMENTS IN ACCIDENTS: variable Z is the number of accidents in which the driver was involved over the two-year period between August 1980 and July 1982.

APPENDIX B

PARTIAL LIST OF DRIVING INFRACTIONS AND CORRESPONDING NUMBER OF DEMERIT POINTS

INFRACTIONS	# OF POINTS
- Not stopping at a stop sign	2
- Illegal backward movement	2
- Not stopping at a red light	3
- Racing	6
- Not stopping at Railway Crossings while driving a bus or a dangerous material carrier	9
- Not stopping for a school bus with blinking lights on	9
- Excess speed:	
* 1 to 14 km/h over limit	1
*15 to 29 " " "	2
*30 to 44 " " "	3
*45 + " " "	4+

APPENDIX C

PARTIAL LIST OF CRIMINAL OFFENSES

BRINGING A LICENSE SUSPENSION

(3, 6 and 12 months respectively for the first, second and third offense over a two-year period)

- Criminal negligence causing death or bodily injuries
- Hit and run
- Dangerous driving
- Refusal of a breath test
- Driving under the influence of alcohol (80 mg/100 ml of blood)

TABLE 1

ESTIMATES OF THE POISSON AND COMPOUND POISSON DISTRIBUTION

k	observed n_k during 1982-83	predicted n_k for 1982-83	
		Poisson ($\hat{\lambda}$=0.0701)	Compound Poisson ($\hat{a}$=0.6960; $\hat{\tau}$=9.9346)
0	17784	17727	17785
1	1139	1242	1132
2	79	43	88
3	9	1	7
4	2	0	1
5+	0	0	0
		χ^2 =55.12	χ^2 =2.16
		$\chi^2_{2,0.95}$= 5.99	$\chi^2_{3,0.95}$=7.82

TABLE 2

THE PROBIT ESTIMATES

(* = significant at 90 % ; ** = significant at 95 % ; NC = not calculated)

Variable	MODEL 1 Original coefficient	(t)	MODEL 1 Transformed coefficient	MODEL 2 Original coefficient	(t)	MODEL 2 Transformed coefficient
X	-	-	-	.055	(9.62)**	0-1 : .006 1-5 : .028 5-31: .434
Y	-	-	-	.290	(2.23)**	0-1 : .039 1-2 : .057 2-3 : .077
Z	.257	(10.12)**	0-1 : .032 1-2 : .046 2-6 : .327	.211	(8.11)**	0-1 : .025 1-2 : .034 2-6 : .239
CONSTANT	-2.128	(-10.21)**	NC	-2.295	(-10.30)**	NC
A16	-.323	(-0.95)	-.027	-.304	(-0.89)	-.025
A2024	-.014	(-0.18)	-.002	-.028	(-0.35)	-.003
A2534	-.224	(-2.60)**	-.022	-.207	(-2.40)**	-.020
A3544	-.330	(-3.53)**	-.031	-.292	(-3.11)**	-.027
A4554	-.350	(-3.58)**	-.031	-.288	(-2.93)**	-.026
A5564	-.482	(-4.62)**	-.038	-.409	(-3.91)**	-.033
A65	-.468	(-3.93)**	-.036	-.372	(-3.11)**	-.030
SEXM	.432	(11.69)**	.044	.370	(9.80)**	.037
EXPO	.054	(0.27)	.006	.227	(1.08)	.029
EXPM1	.050	(0.32)	.006	.116	(0.72)	.014
EXP2	-.157	(-1.22)	-.015	-.145	(-1.10)	-.014
EXP35	-.241	(-1.81)*	-.023	-.245	(-1.79)*	-.022
EXP610	-.239	(-1.66)*	-.023	-.251	(-1.70)*	-.024
EXP11	-.187	(-1.27)	-.020	-.194	(-1.29)	-.021

(continued on next page)

TABLE 2 (continued)

Variable	MODEL 1		MODEL 2	
	Original coefficient (t)	Transformed coefficient	Original coefficient (t)	Transformed coefficient
REG1	.090 (1.10)	.010	.107 (1.30)	.012
REG2	.004 (0.06)	.001	.035 (0.46)	.004
REG3	.046 (0.98)	.005	.073 (1.55)	.008
REG4	.097 (1.61)	.011	.106 (1.75)*	.012
REG5	.021 (0.25)	.002	.025 (0.30)	.003
REG7	.072 (1.31)	.008	.073 (1.32)	.008
REG8	.008 (0.16)	.001	.008 (0.18)	.001
REG9	.216 (3.07)**	.027	.245 (3.46)**	.031
REG10	.142 (1.61)	.017	.128 (1.43)	.015
REG11	.144 (1.34)	.017	.158 (1.46)	.019
RTSA	-.266 (-2.52)**	-.026	-.254 (-2.40)**	-.025
RTSB	.138 (0.54)	.017	.155 (0.60)	.019
RTSCG	-.158 (-1.05)	-.015	-.146 (-0.97)	-.014
RTSD	.040 (0.33)	.005	.034 (0.28)	.004
RTSH	.112 (1.00)	.013	.118 (1.04)	.014
RTSJ	.745 (1.77)*	.138	.736 (1.73)*	.134
RTSK	-.533 (-0.99)	-.037	-.535 (-0.99)	-.037
RTSM	-.272 (-1.56)	-.024	-.273 (-1.55)	-.023
RTSO	.104 (0.47)	.012	.145 (0.67)	.017
RTSQ	-.650 (-0.97)	-.041	-.591 (-0.88)	-.039
RTSU	.343 (1.75)*	.048	.366 (1.86)*	.052
RTSY	-.997 (-2.34)**	-.049	-.977 (-2.31)**	-.048
RTSO	-.189 (-1.75)*	-.022	-.186 (-1.71)*	-.021

(continued on next page)

TABLE 2 (continued)

Variable	MODEL 1 Original coefficient	(t)	MODEL 1 Transformed coefficient	MODEL 2 Original coefficient	(t)	MODEL 2 Transformed coefficient
CL11,12	.145	(1.30)	.018	.158	(1.41)	.019
CL13	-.298	(-0.59)	-.025	-.256	(-0.51)	-.022
CL21	.121	(1.79)*	.014	.127	(1.88)*	.014
CL22	.581	(2.95)**	.097	.560	(2.81)**	.091
CL31	.438	(3.40)**	.066	.359	(2.74)**	.050
CL42	.039	(0.68)	.004	.045	(0.77)	.005
CL54	.038	(0.49)	.004	.041	(0.52)	.004
CL55	-.476	(-1.32)	-.035	-.579	(-1.55)	-.038
CL56	-.120	(-0.20)	-.012	-.104	(-0.17)	-.010
VALA	.001	(1.49)	NC	.001	(0.97)	NC
VALB	-.001	(-1.75)*	NC	-.0002	(-0.42)	NC
VALC	.002	(5.87)**	NC	.002	(5.70)**	NC
nb of observations	19013			19013		
nb of variables	51			53		
Likelyhood ratio	620.99			716.64		
Mean estimated probabilities of accident	0.065			0.065		
Estimated probability of accident for the average individual (Standard error)	0.053 (0.002)			0.052 (0.002)		

TABLE 3

THE OTHERWISE AVERAGE INDIVIDUAL'S PROBABILITY OF ACCIDENT AS A FUNCTION OF CUMULATED DEMERIT POINTS X

demerit points during 1980-81 and 1981-82	probability of accident for 1982-83 (for Y=Z=0)
0	.043
5	.075
10	.123
15	.188
20	.271

TABLE 4

THE OTHERWISE AVERAGE INDIVIDUAL'S PROBABILITY OF ACCIDENT AS A FUNCTION OF LICENSE SUSPENSIONS Y

number of suspensions during 1981-82	probability of accident for 1982-83 (for X=Z=0)
0	.043
1(VALB=281)[1]	.079
2(VALB=197)[1]	.134

[1] the driver cannot drive during a suspension

TABLE 5

THE OTHERWISE AVERAGE INDIVIDUAL'S PROBABILITY OF ACCIDENT AS A FUNCTION OF PAST INVOLVEMENTS IN ACCIDENTS Z

number of accidents during 1980-81 and 1981-82	probability of accident for 1982-83	
	for X=Y=0	for X=5 and Y=1(VALB=281)
0	.043	.128
1	.066	.177
2	.098	.238
3	.140	.307
4	.192	.385
5	.255	.468

TABLE 6

AVERAGE NUMBER (#) AND PERCENTAGE (%) OF PERIODS
THE AVERAGE INDIVIDUAL WILL BE WRONGLY PENALIZED

contract		$\gamma = 4$		$\gamma = 10$	
		RY	BD	RY	BD
50-period (1000 cases)	#	2.08	2.12	0.52	0.44
	%	4.16	4.24	1.03	0.89
100-period (1000 cases)	#	3.47	3.54	0.75	0.74
	%	3.47	3.54	0.75	0.74
1000-period (100 cases)	#	5.68	5.28	0.75	0.60
	%	0.57	0.53	0.08	0.06